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INSIDE

Learning Progressions in Science

A new approach emphasizes sustained instruction in big ideas

by Patti Hartigan

Candace Chick is the first to admit that she's not an expert in science. Far from it, the teacher at the Samuel W. Mason Pilot Elementary School in Roxbury, Mass., only took one basic science class during her undergraduate and graduate studies and, until recently, quaked at the idea of teaching the properties of matter to her fifth-grade students. "I have always been insecure about science," she says. "It is not one of my strengths."

But now, she is positively ebullient about the progress both she and her students have made in the subject. Her class has been investigating molecular change, conducting hands-on experiments, and watching computer simulations. The students' knowledge has grown deeper than simply being able to define terms like "condensation" and "evaporation." They readily discuss their ideas and frequently engage in polite, intellectual arguments that influence each others' learning. "Their knowledge isn't, 'Oh, there is a puddle on the sidewalk and when the sun comes out it evaporates and goes magically into a cloud and then it comes down again when it rains,'" Chick explains. "They understand how those molecules start to move and bounce around like mad as they evaporate. They really understand this in a way that they didn't before."

Chick's class just completed the third year of a research endeavor called The Inquiry Project, a partnership between teachers, TERC, and Tufts University that teaches concepts like weight, volume, and density in grades 3–5 to lay the foundation for later introduction to molecular theory. In third grade, students begin exploring materials and then move on to investigating weight and volume, using density cubes and balance scales, among other tools. They proceed from comparing the "felt weight" of cubes made from different materials to measuring actual weight on a balance scale. They ask questions along the way. Can two objects of the same size weigh different amounts? Does a tiny piece of clay have weight? The students are asked to discuss their findings at every step: the goal of this "productive talk" is to lead to deeper understanding.

Researchers contend that the traditional model of science instruction doesn't jibe with how students actually learn.

Chick worked with an Inquiry Project coach, who not only helped her overcome her inhibitions about science but also encouraged her to lead productive class discussions. Her students receive four extra hours a week of science instruction—a bonus that is unheard of in most, if not all, elementary school classrooms. And it's paying off. "They have started to understand that everything has weight and volume, which is a really big deal. I never recall getting to a point where kids would be able to articulate this stuff," she says.

No More Six-Week Units

The Inquiry Project is a working example of how to teach a learning progression in science, and it represents cutting-edge research that aims for a dramatic restructuring of the way science is taught. Researchers contend that the traditional model of science instruction—with many disjointed topics being taught in short units at each grade level and little continuity from year to year—doesn't jibe with how students actually learn. Current instruction emphasizes facts and definitions, rather than a deep understanding of key concepts and processes.

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In contrast, a learning progression focuses on a big idea, such as molecular theory, and offers dedicated instruction that fosters sustained incremental learning over several years. This differs radically from how science is typically taught today. "In the case of matter, you may have a unit in grade one and then not touch the topic until middle school," says Carol L. Smith, a cognitive developmental psychologist at the University of Massachusetts Boston who is part of the Inquiry Project research team and is a pioneer in learning progressions research. "If you are going to prepare students, you have to develop a network of concepts, not just topics, and devise instructional units that move ideas forward to prepare kids to take the next step."

A learning progression, then, is not a six-week unit on, say, whales. "There is no tradition in science education in thinking about long-term development," says Leona Schauble, professor of education at Vanderbilt University. "I'm talking about people thinking about the span of an idea from kindergarten on through high school and beyond. It is more typical for science educators to work for six weeks."

Little children are already theorists with knowledge—and with misperceptions about key science concepts.

An Emergent Field

Researchers like Schauble and her Vanderbilt colleague Richard Lehrer have been studying learning progressions for more than a decade, but the field is still in its emergent stages. The groundwork was laid by two seminal National Research Council reports: *How People Learn* (2000) and *Taking Science to School* (2007). Around the same time, the American Association for the Advancement of Science developed the *Atlas of Science Literacy* for science instruction, which introduced the idea of teaching key science concepts over a number of years. These so-called "atlas maps" chart learning goals in core science topics, beginning with goals for kindergarten and moving on through grade 12. A draft framework to be used in formulating new national science standards may incorporate learning progressions, and is expected to be released in July by the National Research Council (see "Learning Progression and Standards," p. 3).

But what exactly is a learning progression? According to a recent report by the Consortium for Policy Research in Education at Columbia University's Teachers College, learning progressions are "empirically grounded and testable hypotheses about how students' understanding and ability to use knowledge and skills in core school subjects grow and become more sophisticated over time with appropriate instruction."

Learning progressions are not benchmarks, but rather descriptions of how children's thinking evolves over time. *Taking Science to School* defines the idea this way: "Learning progressions are descriptions of successively more sophisticated ways of thinking about a topic that can follow one another as children learn about and investigate a topic over a broad span of time."

These progressions, or trajectories, as they are also known, are concerned with how students learn and, as a result, must take into account what the youngest students know and how they think when they arrive at school. According to Gregg Solomon, program director of cognitive science at the National Science Foundation, the field of science education is only now catching up with recent developments in cognitive science and psychology. Little children, he explains, are not blank slates when they arrive at school. They are already theorists with knowledge—and with misperceptions about key science concepts. Instruction must take that into account. "A lot of assumptions being made about the nature of learning are wrong," Solomon says.

The field is in its infancy, and researchers are far from having curriculum, assessments, and professional development tools ready to use in schools nationwide. "I describe this as similar to looking at an ancient Greek mosaic," says Tom Corcoran, codirector of the Consortium for Policy Research in Education at Teachers College, Columbia University and coauthor of its recent report on learning progressions in science. "You are seeing pieces of a picture painted 2,000 years ago. You have some remnants of it mapped in, and you can make some inference about what the whole picture looks like, but there are large areas where very little work has been done."

Consider, for instance, the study of the earth and the solar system. Research (done by Julia Plummer at Arcadia University) shows that preK–2 students can describe the daily pattern of the motion of the sun from east to west. In grades 3–5, they can explain this pattern based on the earth's rotation. But the research on student understanding ends there. At this point, researchers can only guess that the next step is for middle school students to conceptualize the difference between the earth's rotation versus the earth's orbit.

Given that science itself is such a huge area with so many different disciplines, the field is rife with questions. How many years should a learning progression span? What is a big idea and which ones lend themselves to progressions? How must progressions be altered depending on the conditions under which they are being taught?

That said, there is general agreement that the current method of instruction is insufficient or, to use the oft-quoted phrase, "a mile wide and an inch deep." Science instruction today produces students who may be capable

For additional sidebars, "Tackling Misconceptions in Science" and "Example of a Learning Progression," read the online version of this article at **www.edletter.org.**

of regurgitating facts or doing equations without understanding what those facts and equations really mean. Charles Anderson, professor of teacher education at Michigan State University, refers to this kind of instruction as "procedural display." He explains, "Students are learning, for example, to balance a chemical equation without realizing that balancing a chemical equation is really a way of saying that atoms are not created or destroyed."

In order for learning progressions to succeed, they must begin by assessing what students know and then chart a pathway to take them where they need to go. "You have to take the students' perspective into account," says Amelia Gotwals, assistant professor of education at Michigan State University and co-organizer of the Learning Progressions in Science Conference, which was held last year in Iowa City. "The previous standards have been based on what scientists say, but they don't identify the common ideas and misperceptions that students bring with them. How can we design curriculum and standards that take those things into account?"

Challenging Misconceptions

That, of course, is the key question, and the researchers agree that there is no definitive answer yet. That said, Anderson of Michigan State has developed an environmental literacy curriculum for grades 4–12 that begins by acknowledging the notions that elementary students bring with them to class and builds from there.

Consider, for example, the carbon cycle. The goal is to shift the students' way of thinking from what Anderson calls "force-dynamic reasoning" to what he terms "scientific discourse." Force-dynamic reasoning, typical in elementary school, is a way of viewing the world in terms of "actors" with purposes. For instance, the main purpose of a tree (the "actor") is to grow, and in order to grow, it needs water, air, sunlight, and soil. However, the scientific explanation is that the tree uses the sun as an energy source to convert carbon dioxide and water into glucose, which is the building block of the tree. "The scientific story is one of transformation of matter and energy," Anderson explains. "If we are interested in preparing kids to think about carbon in our atmosphere and in our various environmental systems and how it effects global warming, we have to make the transition from force-dynamic reasoning to scientific reasoning, where they are thinking about matter and energy."

The fourth-grade curriculum outlines a pathway toward that transition in thinking. It's not about memorizing definitions of, say, photosynthesis, but about actually transforming how students think. Students begin by watching time-lapse videos of plants growing. They then grow plants under different conditions—with or without water and light. They measure the results over time and ultimately determine that plants need water, air, and light to grow. They then examine plants on a microscopic level and learn about their cellular makeup, which leads to an exploration of how plants make their own food and where they store it.

Through tending the plants and watching them grow, students can begin to view the plants not as actors, but as part of an ecosystem. Anderson and his colleagues are still generating data on what works, but the goal is for the students to understand basic underlying principles of science, such as conservation of matter and energy. "Facts alone," he says, "are not enough." ■

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Learning Progressions and Standards

Researchers studying learning progressions hope that their work will have an impact on science standards at both the state and national levels. Current science standards, they say, focus primarily on facts rather than concepts and processes, and they are too broad because they are set by committees of self-interested scientists. "Everyone wants to make sure their important content is in the standards, so they cover everything at every grade, and they don't think of learning as a sequence," says Tom Corcoran, codirector of the Consortium for Policy Research in Education at Teachers College, Columbia University.

Massachusetts, known for its rigorous state standards, is in the forefront of the states in terms of revising its standards to incorporate learning progressions, Corcoran says. Jake Foster, director of science and technology/engineering for the Massachusetts Department of Education, has solicited summaries from key learning progressions researchers. The new framework, due out early next year, aims to correct what Foster calls "opportunity to learn" gaps as well as to address student misperceptions about key science concepts.

Researchers caution, however, that standards simply outline *what* students need to know, not *how* they are going to learn it. "The hard work is not in the standards writing. The hard work is in the implementation and in building a common understanding [among teachers] of what these things mean," says Jo Ellen Roseman, director of Project 2061 of the American Association for the Advancement of Science. Teachers, however, face time constraints and lack of content knowledge.

Nevertheless, the current form of instruction, science experts say, is inadequate. "If we are going to change the way kids learn, it has to happen in the classroom, not by large-scale policies," says Charles Anderson of Michigan State. "We need to find ways of supporting teachers to change what they are doing in the classroom. And that won't happen overnight. It is going to take the rest of my career, for sure."

For Further Information

Causal Patterns in Science: A Professional Development Resource: **http://www.cfa.harvard.edu/smg/Website/UCP/**

Conceptual Framework for New Science Education Standards. The Board on Science Education, Center for Education, Division of Behavioral and Social Sciences and Education, National Research Council. Available online at **http://www7.nationalacademies.org/bose/Science_Standards_Framework_Homepage.html**

T. Corcoran, F.A. Mosher, and A. Rogat. *Learning Progressions in Science: An Evidence-based Approach to Reform*. Consortium for Policy Research in Education, Center on Continuous Instructional Improvement, Teachers College, Columbia University, 2009. Available online at **http://www.cpre.org/ccii/images/stories/ccii_pdfs/lp_science_rr63.pdf**

Environmental Literacy. Michigan State University: **http://edr1.educ.msu.edu/EnvironmentalLit/index.htm**

The Inquiry Project: **http://inquiryproject.terc.edu/**

Learning Progressions in Science Conference: **http://www.education.uiowa.edu/projects/leaps/proceedings/Default.aspx**

Understandings of Consequence Teacher Resource: **http://www.pzweb.harvard.edu/ucp/**

Putting the "Boy Crisis" in Context

Finding solutions to boys' reading problems may require looking beyond gender

by Michael Sadowski

"The Boys Have Fallen Behind." "Girls Lead the Nation in Reading Scores." "Are Teachers Failing Our Sons?" Earlier this year, newspapers across the country ran these and other headlines in response to a March report by the independent Center on Education Policy (CEP) in Washington, D.C. The report, which outlined results on state accountability tests, raised alarm by noting that the percentage of boys scoring "proficient" or higher in reading was below that of girls at *all* grade levels tested and in *every* state for which sufficient data were available.

Results for the 2009 National Assessment of Educational Progress (NAEP), also released in March, showed similar patterns (see sidebar figures 1 and 2, p. 5). Boys in all 50 states and the District of Columbia, at both grades 4 and 8, reached each of the three NAEP reading achievement levels (basic, proficient, and advanced) at lower rates than girls with only two exceptions—and in those cases, boys and girls were essentially tied.

Much of the debate centers on whether a widespread "boy crisis" even exists.

Girls have been posting higher reading scores than boys for decades, but other trends suggest they may also have surpassed boys in overall academic performance. On standardized mathematics tests, results vary: Girls are not decisively ahead of boys, but they're not significantly behind either. Girls have higher high school grade-point averages, are more widely represented as school valedictorians, and attend and graduate from college in greater numbers than boys. All this has educators, researchers, and journalists debating: Are the boys in U.S. schools in crisis, and, if so, what should educators be doing differently to help them succeed?

Concerns that boys are at serious academic risk have been in the national spotlight before. In a *Washington Post* op-ed piece published in April 2006, Caryl Rivers of Boston University and Rosalind Chait Barnett of Brandeis University noted that worries about a "boy crisis" go back at least as far as the early 1900s, when they say writers of monthly magazines and books warned "that young men were spending too much time in school with female teachers and that the constant interaction with women was robbing them of their manhood."

The most recent concerns about boys focus largely on literacy skills. Journalist Richard Whitmire, author of the 2010 book *Why Boys Fail: Saving Our Sons from an Educational System That's Leaving Them Behind*, argues that many boys' literacy deficits put them at a disadvantage not just in English language arts but across the curriculum. "Many state math assessments contain nothing but word problems, as do the SAT and ACT college admissions tests," notes Whitmire. "What has gone unnoticed is that many boys can't wade through the puzzling words and sentences to get to the actual math calculation."

Whitmire also devotes a chapter in his book to the "ideological stalemate" that, he says, has dominated the research and reporting on boys' academic struggles for years. On one side are educators, researchers, and reporters who use data about gender gaps and brain research to argue for single-sex education and widespread changes to school practices and curricula to make them more "boy-friendly"; on the other side are those who say these sorts of changes could disadvantage girls—who all evidence suggests will face discrimination when they enter the workforce. (A recent report by the women's business group Catalyst, for example, found that among recent MBA graduates, men started at higher positions and earned on average $4,600 per year more than women in their first post-degree jobs.)

Much of the debate centers on whether a widespread "boy crisis" even exists. Barnett, a senior scientist at Brandeis University's Women's Studies Research Center and coauthor with Rivers of the book *Same Difference: How Gender Myths Are Hurting Our Relationships*, argues that all learners, regardless of sex, are more different from one another than they are similar and rejects "categorizing all boys' reading and all girls' reading and talking about a boy crisis."

Yet while arguments on both sides of the debate may have their merits, evidence suggests that reading deficits at the school, district, and even state level may require solutions that emphasize "context" rather than "crisis."

A Universal Problem?

One reason gender gaps in reading have captured so much attention is that they seem universal. On the most recent (2006) Progress in International Reading Literacy Study, which measured performance on fourth-grade reading tests and other literacy indicators in 40 countries around the world, girls outscored boys in all educational systems from which sufficient data were available.

In the United States, the gaps also seem to hold across differences in race, ethnicity, and family income. A 2006 report on NAEP scores by researchers at the Urban Insti-